30 | OPP#34134

33pp

(7-1-96)

FENAMIPHOS MITIGATION WORKGROUP

MITIGATION RECOMMENDATIONS FOR GROUND AND SURFACE WATER

Estella Waldman (EFED; lead)
Laura Parsons (EFED)
Henry Nelson (EFED)
Dick Felthousen (EFED)
Sharlene Matten (EFED)
Kathleen Depukat (SRRD)
Ron Kendall (SRRD)
Jim Stone (RD)
Rich Michell (BEAD)
Eric Maurer (BEAD)
Jane Smith (HED)

July 1, 1996

EXECUTIVE SUMMARY

BACKGROUND

Available ground-water monitoring data for fenamiphos and its degradates are very limited. However, data from studies in a hydrogeologically vulnerable area of Florida indicate that fenamiphos residues leach to ground water as a result of normal agricultural use, exceeding levels of concern for human health and ground-water quality. Fenamiphos also has the potential to contaminate surface water resources. In response to these concerns, the Fenamiphos Mitigation Workgroup was formed to develop a set of mitigation recommendations to be incorporated into the Reregistration Eligibility Document (RED).

This report recommends mitigation options that are intended to reduce the exposure to fenamiphos residues in ground and surface water. In order to arrive at these recommendations, we used information about: the surface- and ground-water monitoring data presently available to the Agency; fenamiphos toxicity in relation to human health and ecological effects; fenamiphos use and usage; and the effect of alternative nematicides on water resources. Also considered were the mitigation options presented to the Agency by the registrant on October 26, 1994 and January 1, 1995. Although this document concentrates on the reduction of residues in water resources to protect human health and water quality, some of the mitigation options may also indirectly reduce the effect of fenamiphos on terrestrial or aquatic wildlife. It is also likely that the adoption of many or all of these mitigation measures will result in greater exposure reduction; i.e., an additive effect will probably be seen.

Please note that when the phrase "fenamiphos residues" is stated in this document, it refers to fenamiphos parent and/or its degradates.

SUMMARY OF REGULATORY OPTIONS

Available data indicate that fenamiphos can impact ground-water quality in vulnerable areas. Fenamiphos also has the potential to affect surface-water resources. Therefore, recommendations have been developed to reduce the impact on water resources. In brief, the mitigation options recommended in this document are:

I. Suspend or Cancel or Phase-out or Manage fenamiphos use on the Central Ridge of Florida and other similar areas in the U.S.*

1. Voluntary cancellation/EPA cancellation; or
2. Phase-out fenamiphos use:
   a. Use nematode resistant and nematode-free stock, and
   b. Use IPM; or
3. Develop an agreement between the registrant, Florida, and EPA to manage fenamiphos on the Ridge; allow Florida to manage this restriction; or
4. Suspend fenamiphos use in areas similar to the Central Ridge of Florida.

(2)

* The suggested mitigation options will help to reduce fenamiphos concentrations in ground water. However, continued use of fenamiphos in this area will probably not reduce exposure levels below the 2 ppb HAL.

II. Restrictions

1. <u>All States (All Uses)</u>
   - a. Revise label to prohibit prophylactic use;
   - b. Revise all fenamiphos label rates to reflect lowest rates necessary for efficacy;
   - c. Propose fenamiphos as a candidate for restricted use for ground-water concerns;
   - d. Establish well setbacks for drinking water wells;
   - e. Allow only one application per season in turf (the registrant needs to check on feasibility);
   - f. Mandatory use of slit applicators on turf (the registrant needs to check on feasibility); and
   - g. Add a surface water advisory to the label.

2. <u>Florida</u> - In addition to the mitigation options listed above, the following are specific to Florida:
   - a. More restrictive well setbacks than above;
   - b. Dry season application in citrus;
   - c. Apply only to mature trees on the Central Ridge; and
   - d. Apply every other year on the Central Ridge.

III. Data gathering and education

1. <u>All States</u>
   - a. Establish an educational program about ground and surface water contamination that incorporates various IPM measures;
   - b. Request additional ground-water monitoring consistent with the OPP triggers workgroup criteria;
   - c. Request monitoring in surface waters and surface-source water supply systems which drain watersheds receiving high fenamiphos applications;
   - d. Research on efficacy reduction in fenamiphos use areas; and
   - e. IPM recommendations.

2. <u>Florida</u>
   - a. Detailed monitoring in specific areas.

3. <u>Hawaii/Puerto Rico</u>
   - a. Request a vulnerability assessment for pineapple-growing areas.

(3)

Because of its chemical characteristics, fenamiphos is a pesticide that will leach to ground water and/or runoff to surface water in areas where water resources are vulnerable to contamination. Fenamiphos and all the alternative nematicides cited in this document are very toxic to humans and wildlife; all are rated as Toxicity Class I. Most are mobile through the soil profile and are therefore also potential ground-water contaminants.

In some areas -- the Central Ridge of Florida, for instance -- it is likely that the only mitigation option that will bring fenamiphos concentrations in ground water below our level of concern (HAL = 2 ppb) for human health is use prohibition. Unfortunately, at the present time, there are no viable nematode control alternatives to fenamiphos for citrus on the Central Ridge and all of the alternatives for other crops are likely to contaminate ground water and pose risks to human health and the environment. Because this is such a complex issue, the Workgroup believes that EPA should examine all of the nematicides in a comprehensive manner. EPA should take the initiative with this group of pesticides to determine their relative risks and develop a consistent strategy to mitigate these risks. Some options for consideration are to:

1. Encourage all of the pesticide companies to develop safer, alternative nematicides;

2. Encourage growers to understand that nematicides should be used as a last resort and that nonchemical options may also be effective. The U.S. Department of Agriculture (including extension services), universities, and growers should be encouraged to experiment with other methods of minimizing or eliminating nematicide use;

3. Encourage nematode-resistant crop breeding programs;

4. Conduct a nematicide-cluster analysis within OPP; and/or

5. Place all of the nematicides into Special Review to evaluate relative risk as a group. Some of the nematicides (aldicarb, Telone) are already in Special Review. NOTE: Not all of the team members agree that Special Review will add to the assessment of the risk and benefits for fenamiphos in ground and surface water.

FENAMIPHOS MITIGATION WORKGROUP REPORT

The recommendations presented in this document are the result of Fenamiphos Mitigation Workgroup meetings held during May and June 1996, and interviews with state agency representatives and professionals in the fields of agriculture and turf cultivation. The report is presented in two sections that present background information on fenamiphos and recommendations for mitigation measures. The background section includes fenamiphos toxicity, ground- and surface-water impacts, use/usage, and an alternatives assessment. The recommendation section presents the recommendation options, the rationales for why the options are presented, the certainty that the options will reduce exposure, and the negative aspects of the options.

The Workgroup drew on the expertise of all the parties involved in the preparation of the EFED RED chapter for fenamiphos, including EFGWB, EEB, SACS, SRRD, and HED. The team was supplemented by representatives of BEAD and RD who provided use and usage data as well as information about currently registered and future alternatives. Since the primary ground-water contamination problem to date is in Florida, Wyndham Riotte and Dennis Howard, members of the Florida Department of Agriculture and Consumer Services, were consulted throughout the development of this document.

All of the above representatives were included so that effective mitigation measures could be developed based on a better understanding of where fenamiphos is used. The design also allowed risk managers to be involved in the development of the mitigation strategies and to understand the justification for these recommendations.

BACKGROUND

TOXICITY

The Health Effects Division RfD Peer Review Committee met on May 20, 1993 and determined the reference dose (RfD) for fenamiphos to be 0.0001 mg/kg/day on the basis of a NOEL of 0.01 mg/kg/day for plasma cholinesterase inhibition observed at 0.03 mg/kg/day in a 1-year feeding study in dogs (MRID # 42183601, 42684801). An uncertainty factor of 100 was used to account for interspecies extrapolation and intra-species variability. The degradates, fenamiphos sulfone and fenamiphos sulfoxide, are also cholinesterase inhibitors.

Further, the high dose levels tested in rats and mice were considered adequate for carcinogenicity testing in rats and mice. The treatment did not alter the spontaneous tumor profile in these strains of rats and mice. Fenamiphos was classified as a "Group E" carcinogen - evidence of non-carcinogenicity for humans based on adequate studies in two animal species. This Committee also determined that there was no evidence to suggest that fenamiphos was associated with significant developmental or reproductive toxicity under the testing conditions.

The lifetime adult health advisory level for fenamiphos has been established at 2 ppb. The acute 1- to 10-day health advisories are 9 ppb.

Based on laboratory toxicity data, fenamiphos, as a granular and/or emulsifiable concentrate, exceeds both the acute high risk and chronic level of concern for terrestrial, fresh water, and marine/estuarine organisms. Additional information including EECs, the results of a mesocosm study, and actual field incidents confirms that fenamiphos exceeds the high risk level of concern for freshwater and marine/estuarine organisms.

GROUND-WATER IMPACTS

Because of its chemical characteristics, fenamiphos is a pesticide that will leach to ground water in vulnerable areas. Parent fenamiphos is relatively mobile with Kd values in four soils ranging from 0.95 to 3.4 mL/g, and Koc values from 166 to 543. From laboratory studies, the sulfoxide and sulfone metabolites are more mobile than the parent. Parent fenamiphos has the potential to be moderately persistent under certain conditions. Although the aerobic half-life is short, the anaerobic soil metabolism half-life for the parent is approximately 88 days (13 weeks) which indicates that it will persist once it reaches ground water. Persistence data are incomplete for the degradates but they appear to be at least as persistent as the parent in soil. Also, both fenamiphos sulfoxide and sulfone have been detected in ground water in Florida, indicating that they are both sufficiently persistent to leach in some environments.

Ground-water monitoring data available to the Agency for fenamiphos is not extensive. The two major use states, California and Florida have monitored for this pesticide but fenamiphos is also used in 27 other states where no monitoring data are available. Fenamiphos and its degradates are not analytes in the Safe Drinking Water Act.

Florida

Central Ridge (see Figures 1 and 2 for locations of detections)

Fenamiphos was detected in ground water during a small-scale retrospective ground-water study conducted on citrus in 1989. **Concentrations in ground water ranged up to 22.5 ppb, 204 ppb, and 19.9 ppb for the parent, sulfoxide degradate, and sulfone degradate, respectively**. The highest level of total residues detected in ground water during one sampling event was 239 ppb.

Fenamiphos residues have been detected in the ongoing small-scale prospective study on citrus. The most recent data available (seven months or 209 days following application) indicate that fenamiphos residues were detected in seven out of the nine onsite wells and in two offsite wells. **Concentrations of fenamiphos, fenamiphos sulfoxide, and fenamiphos sulfone ranged up to 0.58, 83.31 and 3.32 ppb, respectively**, in shallow wells in the surficial aquifers. Total residues in one sample ranged up to 87.2 ppb.

(6)

Figure 1. Area Where Monitoring Results Show Fenamiphos Detections Exceeding 2 ppb (Highlands County, FL)

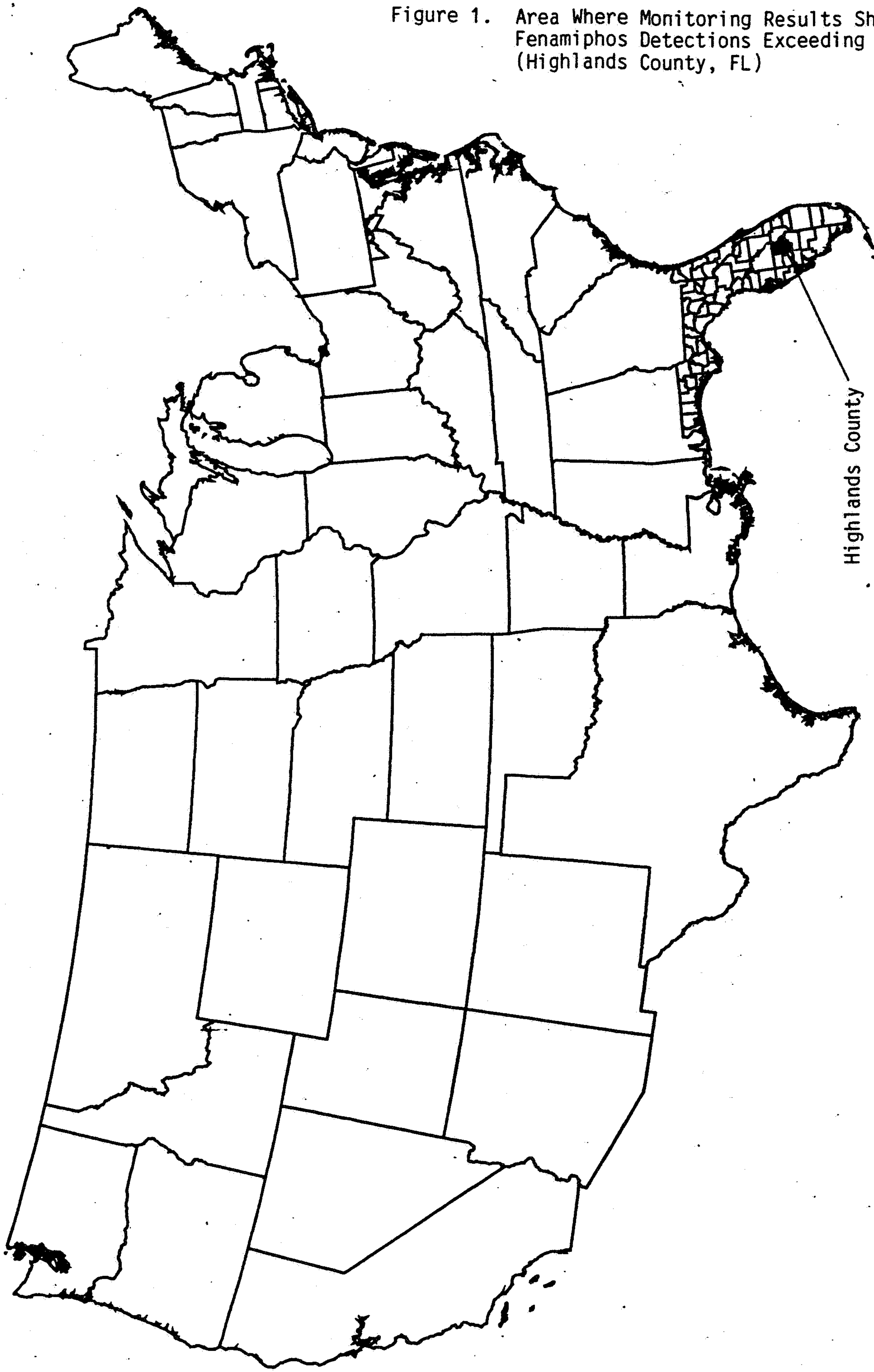
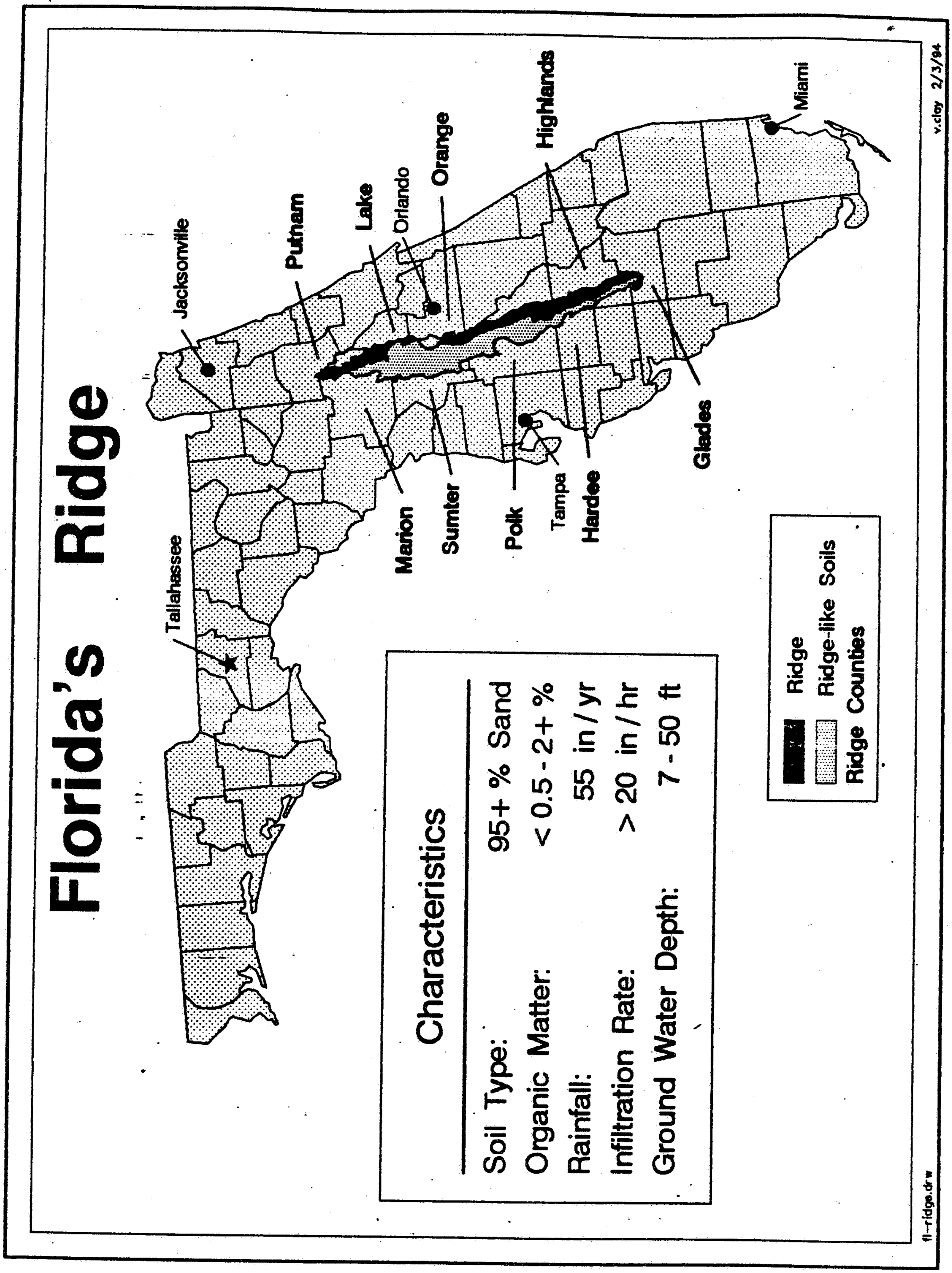


Figure 2. Florida's Central Ridge



from Bayer (1994)

Other areas in Florida

Fenamiphos residues were detected in ground water on five out of nine golf courses in a study conducted by the U.S. Geological Survey. Soils varied from fine sands with good drainage (citrus-growing soils) to Flatwoods soils with poor drainage. Maximum concentrations in ground water were 0.71, 0.75, and 0.10 ppb for fenamiphos, fenamiphos sulfoxide, and fenamiphos sulfone, respectively (higher concentrations were found in the poorly-drained soils).

California

In California, fenamiphos was placed on the State's Ground Water Protection List. The List was created so that monitoring could be conducted for certain pesticides for which there was a ground-water concern. Samples were collected from 40 drinking water wells in six counties in the fenamiphos use area in 1990-91 and 1993-94. Using a detection limit of 0.1 ppb, no fenamiphos residues were detected. Other monitoring has been conducted from the mid-1980's to the present. No detections were seen in any of these wells but detection limits varied from 0.05 to 100 ppb.

Other Monitoring Data

From the *Pesticides and Ground Water Database* (Hoheisel et al., 1992):

Mississippi

In Mississippi, fenamiphos is not widely used (primary crops are turf and ornamentals). A statewide ground-water monitoring survey was designed to sample for pesticides in major crops such as cotton and soybeans. To date, 348 wells have been sampled for fenamiphos and its degradates. No residues have been detected. However, monitoring has been conducted in non-fenamiphos use areas using a detection limit of 5.0 ppb for the parent.

Oregon

Since 1986, approximately 1000 ground-water samples have been analyzed for parent fenamiphos (no degradates have been analyzed). Using a 0.2 ppb Minimum Detection Limit, no residues have been found.

Texas

From 1987 to 1988, 188 rural wells in eight counties were sampled. The analyses were made using an immunoassay screen for organophosphates including fenamiphos - no organophosphates were detected. Wells may have been near fenamiphos use areas in some counties but this cannot be confirmed.

Washington

Since 1988, 248 private drinking water wells in eight study areas have been sampled. Using a detection limit that varied from 0.12 to 0.3 ppb, samples were analyzed for parent fenamiphos only. No parent residues have been detected but it is not known whether there is any connection between the sampled wells and the fenamiphos use area.

SURFACE-WATER IMPACTS

EFED has limited data on the concentrations of fenamiphos in surface water. As mentioned above, water supply systems are not required to sample and analyze for fenamiphos since it is not currently regulated under the Safe Drinking Water Act (SDWA).

Fenamiphos has the potential to contaminate surface water via ground spray drift, tile drainage flow, and runoff. The typical incorporation of fenamiphos into the soil should limit the fraction available for runoff. However, relatively high application rates coupled with only moderate susceptibility to biodegradation may make substantial quantities of fenamiphos within approximately the top cm remain available for runoff for several weeks post-application (aerobic soil metabolism half-lives of 7-30 days). Although fenamiphos is susceptible to rapid photodegradation on soil, only approximately the top mm of soil is typically exposed to solar irradiation. The rest of the chemical in the top cm and below will not be exposed. Its relatively low soil/water partition coefficient (Kds of 1-4; ARS/SCS Koc value of 100) coupled with typically much higher runoff volumes than soil loss indicates that runoff will be primarily via dissolution in runoff water rather than adsorption to eroding soil.

The susceptibility of fenamiphos to rapid direct aqueous photolysis (half-life of 2-4 hours) should greatly limit its persistence in clear, shallow water. However, its resistance to abiotic hydrolysis, its low potential for volatilization from surface water (Henry's Law constant = 1.0×10^{-9} atm.*m^3/mol), and only a moderate susceptibility to biodegradation should make its persistence longer in deeper and/or unclear waters, particularly those with low microbiological activities and long hydrologic residence time. An anaerobic soil metabolism half-life of >60 days indicates that it may be substantially more persistent in typically anaerobic sediment/lower water column than in the typically aerobic upper water column. The soil/water partitioning of fenamiphos indicates that its concentration in sediment pore water at equilibrium will be comparable to or somewhat lower than its concentration adsorbed to suspended and bottom sediments. Concentrations in the water column near the sediment interface should be comparable to those in sediment pore water but somewhat lower farther up in the water column.

The sulfoxide and sulfone degradates are reported to be at least as persistent as fenamiphos in soil and more mobile as indicated by substantially greater vertical mobility in terrestrial field dissipation studies than fenamiphos. Consequently, they will be available for runoff at least as long, also susceptible to tile drainage to surface water and runoff will probably also be via primarily by dissolution in runoff water. Like fenamiphos, they will probably also tend to partition into surface water with dissolved concentrations comparable to and possibly greater than concentrations adsorbed to suspended and bottom sediment. The relatively low soil/water partitioning of fenamiphos and its sulfoxide and sulfone degradates indicate that their bioaccumulation potential is probably relatively low.

Fenamiphos is of potential concern to surface water because of its toxicity to fish and aquatic invertebrates. The Agency has records of five fish kills that occurred from the golf course use. Fenamiphos is also of concern to surface-source drinking water because of its relatively low lifetime health advisory and its relatively low soil/water partitioning.

The sulfoxide and sulfone degradates appear to be at least as persistent and more mobile than fenamiphos and may have at least comparable toxicity to nontarget organisms. Therefore, they are also of concern for surface water and surface-source drinking water.

Florida

The South Florida Water Management District (Miles and Pfeuffer 1994) summarized fenamiphos data from 27 surface-water sites within the SFWMD from June 1989 through November 1993. Using relatively high detection limits (0.6 to 1.6 ppb), fenamiphos was not detected in approximately 756 samples.

STORET

A STORET search resulted in a listing of 37 samples over 20 sites in three states. Fenamiphos was not detected in any of the samples at detection limits ranging from 0.04 to 0.75 ppb. No information is provided in STORET about whether samples were taken from fenamiphos use areas.

USE/USAGE

Approximately 835,000 - 1.5 million pounds of fenamiphos active ingredient were applied to 250,000 - 500,000 acres annually from 1993 to 1995. As illustrated in Table 1, turf (32 - 48 percent), grapes (11 - 16 percent), tobacco (12 - 13 percent), and citrus (5 - 18 percent) account for nearly 80 percent of all fenamiphos usage. Cotton, peanuts, and peaches are the three other major usage crops for fenamiphos.

Based on information provided by the registrant and crop specialist information from many of the major usage states associated with each of the six sites of concern, BEAD compared the typical application rates and numbers of applications with the registrant's proposed risk mitigation measures (i.e., reducing maximum use rates, etc.). The average application rate for turf was about 10 pounds of active ingredient per acre (pounds AI/A); grapes, 1.5 - 3.0 pounds AI/A; tobacco, 1.0 - 1.3 pounds AI/A; and oranges, 2.5 - 7.5 pounds AI/A.

The market share of fenamiphos usage [calculated as a percentage of all nematicide usage (pounds AI) on that site] varies greatly among all of the sites. The percentage is greatest in grapefruit where fenamiphos accounts for nearly 100 percent of all nematicide usage. The sites that follow, in descending order, are: oranges (80 percent), lemons (82 percent), grapes (33 percent), peppers (28 percent), pineapple (28 percent), and okrá (25 percent).

Considering that potential risk mitigation measures are being targeted to Florida, BEAD felt it would be helpful to present a more detailed usage analysis of the largest fenamiphos uses in that state (citrus and turf). This detailed summary for citrus is provided in Table 2 (Summary of Fenamiphos Usage on Citrus in Florida, 1994-5). A detailed summary of fenamiphos usage on turf was not completed due to a lack of data for the various use sites that fall under this use.

Table 1: Percent of Various U.S. Crops Treated Annually with Fenamiphos, 1993 - 1995

Site	Acres Grown/1 (000)	Acres Treated (000)	Percent Crop Treated	Pounds AI Applied (000)	% of Nematicide Market Share	Major Region or State
Apple	457.1	1 - 2	<1 - <1	1 - 3	<1 - 1	MI and NC
Broccoli/2	110.0	15 - 20	14 - 18	30 - 35	<1 - 1	CA
Brussels Sprout	4.7	<1 - 1	<1 - 21	<1 - 1	15 - 20	CA
Cabbage	99.4	3 - 5	3 - 5	5 - 10	10 - 15	CA and FL
Cauliflower/2	55.3	5 - 10	9 - 18	10 - 15	<1 - 1	CA
Cherry	93.4	1 - 2	1 - 2	1 - 5	<1 - 1	MI
Cotton	13,468.1	10 - 40	<1 - 1	15 - 55	<1 - 1	Nationwide
Grapefruit	142.1	5 - 10	4 - 7	10 - 25	95 - 100	FL and CA
Grape	757.4	50 - 100	7 - 13	135 - 175	20 - 45	CA
Kiwi	7.1	<1 - 1	<1 - 14	<5 - 5	<1 - 1	CA
Lemon	62.6	5 - 10	8 - 16	5 - 25	68 - 95	CA
Nectarine	27.4	<1 - 1	<1 - 4	<5 - 5	1 - <5	CA
Okra	4.3	<1 - 1	<1 - 23	<1 - 1	20 - 30	South
Orange	675.6	5 - 25	1 - 4	25 - 225	70 - 90	FL and CA
Ornamentals	701.6	1 - 5	<1 - 1	10 - 50	Unknown	Northwest
Peach	176.4	3 - 5	2 - 3	5 - 30	1 - <5	CA, MI, and NC
Peanut	1,688.4	25 - 65	2 - 4	50 - 150	1 - 10	Southeast
Pepper (non-bell)	50.8	<1 - 1	<1 - 2	<1 - 1	25 - 30	GA

13

Site	Acres Grown/1 (000)	Acres Treated (000)	Percent Crop Treated	Pounds AI Applied (000)	% of Nematicide Market Share	Major Region or State
Pineapple	23.5	10 - 15	43 - 64	15 - 30	25 - 30	HI
Raspberry	12.2	<1 - 1	<1 - 8	<5 - 5	5 - 10	MI, OR, and WA
Strawberry	49.7	<1 - 1	<1 - 2	<1 - 2	<1 - 1	Nationwide
Tobacco	762.4	75 - 150	10 - 20	100 - 200	1 - 5	Southeast
Turf	25,000.0	20 - 25	<1 - 1	400 - 500	Unknown	Nationwide
Walnut/3	176.0	<1 - 1	<1 - 1	<1 - 1	<1 - 1	CA
Totals		242 - 497		837 - 1,554		

/1 - Acres grown based on USDA, Agricultural Census, and state statistics.
/2 - Usage reflects Section 18's in California ,associated with the temporary suspension of Telone use permits.
/3 - This use is in REFS however, it does not appear on any of the currently registered labels.

Data based on proprietary and non-proprietary sources, USDA, and state statistics.

Note: All other registered sites had either no known usage or no available data. Those sites where BEAD typically has usage data yet no known usage exist include asparagus, eggplant, and garlic. Those sites where no data exist include banana, beets, and plantain.

14

Table 2: Summary of fenamiphos Usage on Citrus in Florida, 1994-5

SITE	Acres Grown (000)/1	Acres Treated (000)/3	Percent Crop Treated	Pounds AI Applied (000)
Grapefruit	127.3	2 - 5	2 - 4	5 - 10
Oranges	562.8	30 - 40	5 - 7	150 - 175
Lemons/2	N/A	N/A	N/A	N/A
Total		32 - 45		155 - 185

/1 -Bearing Acreage. Acres grown based on USDA, Agricultural Census, and state statistics.
/2 -Although usage on lemons is shown in Table 1, this minor usage is limited to mainly California.
/3 -Multiple acres treated reflects multiple treatments to the same acreage.

FENAMIPHOS USES. The following registered use sites are arranged alphabetically within the different site categories. Please refer to LUIS Reports for detailed use information found on currently accepted labeling (e.g., rates, formulation, application method, timing, equipment, restrictions, and other parameters).

AGRICULTURAL CROPS (FOOD/FEED USES)

TERRESTRIAL FOOD+FEED CROP

apple
citrus (all)
cotton
grape
peanuts (all)
pineapple

TERRESTRIAL FOOD CROP

asparagus
banana
beets
Brussels sprouts
cabbage
cabbage, Chinese
cherry
eggplant
garlic
kiwi
nectarine
okra
peach
peppers, non-bell
plantain
raspberry (black, red)
strawberry

AGRICULTURAL CROPS (NON-FOOD/NON-FEED USES)

TERRESTRIAL NON-FOOD CROP

tobacco

ORNAMENTAL CROPS (NON-FOOD/NON-FEED USES)

TERRESTRIAL NON-FOOD CROP

commercial/industrial lawns
golf course turf
ornamental and/or shade trees
ornamental herbaceous plants
ornamental lawns and turf
ornamental non-flowering plants
ornamental sod farms
ornamental woody shrubs and vines

ALTERNATIVES

The BEAD preliminary use/usage analysis for fenamiphos listed several alternative nematicides for the six major crops which make up 86% of fenamiphos sales. These nematicides are oxamyl (citrus in CA; peaches); aldicarb (cotton, tobacco); 1,3-dichloropropene (cotton, peaches; tobacco); metam sodium (peaches); methyl bromide (peaches, tobacco); chloropicrin (tobacco); carbofuran (grapes); isazofos (turf); and ethoprop (turf). For effective control, a nematicide must be registered for the crop as well as act on the specific nematode pest.

Fenamiphos and all the alternative nematicides cited in this document are very toxic; all are rated as Toxicity Class I. Most are mobile through the soil profile and are therefore also potential ground-water contaminants. Nematicides are usually either incorporated or "watered-in" to the root zone which means that there is usually less potential exposure to surface water than is documented with other types of compounds. EFED has not seen any data on the concentrations of fenamiphos in surface water although five fish kills have been reported to the Agency.

Using the reference dose (mg/kg/day) for all the alternatives listed above, fenamiphos is second to the worst for human health. The order of potential human toxicity from the **least** to the **most** toxic is: oxamyl (RfD 0.025), metam sodium (RfD 0.01), carbofuran (RfD 0.005), aldicarb (RfD 0.001), 1,3-dichloropropene (RfD 0.0003), isazofos (RfD 0.0002), **fenamiphos (RfD 0.0001)**, and ethoprop (RfD 0.000015). When available, information about the chemical's carcinogenicity is included in Tables 3 and 4.

The use pattern and environmental fate characteristics for the primary fenamiphos alternatives are briefly summarized below. The summaries are followed by Tables 3 and 4 that contain some of the important chemical properties responsible for pesticide degradation; ground-water detections (wells and concentrations) for these compounds are also noted.

Fenamiphos is a non-fumigant nematicide. Metam sodium, methyl bromide, 1,3-dichloropropene, chloropicrin, and sodium tetrathiocarbonate are all used as preplant soil fumigants and are therefore not alternatives for the majority of fenamiphos postplant uses on grapes, peaches, turf, and citrus. The properties for the fumigant nematicides are included in Tables 3 and 4, but no summaries are given.

Non-fumigant Nematicides

Aldicarb (Temik) is a soil-applied systemic insecticide, acaricide, and nematicide used on a variety of crops. Since aldicarb is less expensive and more effective than fenamiphos for some pests it is often used instead of fenamiphos in cotton and tobacco. However, aldicarb does not control some species of nematodes. Aldicarb is a carbamate and cholinesterase inhibitor, and is listed in Cancer Group D. Aldicarb is a restricted use chemical.

Aldicarb degrades rapidly by microbial metabolism to aldicarb sulfoxide and aldicarb sulfone. Aldicarb residues are somewhat persistent and very mobile through the soil profile. Effective field half-lives ranged up to four months. Laboratory data indicate that parent aldicarb degrades more rapidly under anaerobic conditions than under aerobic conditions. However, half-life estimates in the saturated zone are up to three years for aldicarb residues. Aldicarb residues have been found in ground water in many locations, especially in association with its use on potatoes and citrus. This pesticide is currently in Special Review because of ground-water concerns.

Carbofuran (Furadan) is a broad spectrum insecticide/nematicide used against many soil and foliar pests including nematodes in peanuts, sugarcane, and tobacco. It is a restricted use pesticide for most applications. Carbofuran is persistent with soil aerobic metabolism half-lives of 149-321 days with the shorter half-life in an acidic soil. Carbofuran degrades rapidly by hydrolysis under alkaline conditions, but is stable at pH 7 and lower. Due to its persistence, carbofuran is both a ground-water and surface-water contaminant. It has also been associated with wildlife incidents and is in Special Review because of its toxicity to birds.

Carbofuran has two main degradates, 3-keto carbofuran and 7-phenol carbofuran, which are very mobile.

Ethoprop (Mocap) is an organophosphate contact insecticide/nematicide with granular and emulsifiable concentrate formulations. The label states that ethoprop is effective against several types of nematodes on turf, peanuts, pineapple, and tobacco. Ethoprop is highly toxic to fish and wildlife and is a restricted use pesticide because of dermal toxicity and avian hazard. It may be applied broadcast or band, but incorporation is required for all uses.

Ethoprop is very soluble and somewhat volatile. It is persistent in the laboratory with an aerobic metabolism half-life of 100 days. Ethoprop is known to degrade more rapidly in the field with dissipation half-lives of 36-48 days in Washington and 8-10 days in warmer, wetter soils in North Carolina.

Laboratory studies indicate that ethoprop is mobile with Kd's of 1.1-3.8 mL/g. Ethoprop has the potential to contaminate both ground and surface water although mandatory incorporation for some uses helps mitigate the surface-water concern. To date, ethoprop has not been detected in ground water.

Isazofos (Triumph) is labeled as an insecticide for use on turf, maize, and rice. It is also currently recommended to control turf nematodes in Florida. Isazofos is an organophosphate compound available in emulsifiable concentrates and granules; it is moderately to highly toxic to mammals depending on the formulation. Label restrictions state that: (1) isazofos is extremely hazardous to aquatic organisms, (2) the compound must be watered in with a minimum of 0.5 inches of water immediately following application, (3) there are to be no aerial applications, (4) treated turf may not be grazed or used for animal feed, and (5) isazofos cannot be applied to sandy or loamy sand soils.

Isazofos is not persistent. It degrades by microbial metabolism with aerobic and anaerobic half-lives of 4 and 8 days, respectively. It also degrades by hydrolysis under alkaline conditions with a half-life of 7 days, but is stable at pH 7 and lower. Isazofos is very mobile in sandy and sandy loam soils (Kd <1) and mobile in silt loam and clay soils with Kd's of 2.4 and 3.9 mL/g, respectively. The main metabolism degradate, 5-chloro-3-hydroxy-1-isopropyl-1H-1,2,4-triazole, is somewhat persistent and very mobile. No ground-water monitoring has been conducted for isazofos.

Oxamyl (Vydate) is a possible fenamiphos alternative of uncertain value for citrus in California and peaches in California, Michigan, and North Carolina. It is not likely to be much of an alternative since it can only be applied during citrus and peach nonbearing years. Oxamyl is a carbamate used to control insects, mites and nematodes on field crops, vegetables, fruits and ornamentals. The Vydate label states that it is effective against root-knot (except Javanese), ring, lesion, dagger, sting and burrowing nematodes. It is a restricted use pesticide with a water soluble formulation which is soil applied.

Oxamyl is not very persistent. It degrades by microbial metabolism with half-lives of 11 days under aerobic conditions and 6 days under anaerobic conditions. It is stable to hydrolysis under acidic conditions, but degrades very rapidly as pH increases to a half-life of 3 hours at pH 9. Oxamyl was shown to be very mobile in all soils tested (Kd <1 in all soils tested); and in field studies conducted in California, detectable residues were found in soil samples at the 60- to 90-cm depth at all 3 sites. To date, oxamyl has been detected in ground water in four states.

TABLE 3. NON-FUMIGANT NEMATICIDES

LEAST HUMAN TOXICITY ⟶ MOST HUMAN TOXICITY

parameter	oxamyl	carbofuran	aldicarb	isazofos	fenamiphos	ethoprop
vapor pressure (torr)	2.3×10^{-4}	5.2×10^{-7}	1.0×10^{-4}	1.3×10^{-4}	1.3×10^{-6}	3.5×10^{-4}
aqueous solubility[a]	2.8×10^{5}	7.0×10^{2}	6.3×10^{3}	1.50×10^{2}	4.0×10^{-2}	7.5×10^{2}
hydrolysis half-life	stable at pH 5, 8 days at pH 7 and 3 hours at pH 9	stable at pH $\leq$ 7, 15 hours at pH 9	stable	stable at pH $\leq$ 7, 7 days at pH 9	stable	stable
photolysis half-life	7 days	6 days	NA	NA	2-4 hours	NA
aerobic soil metabolism half-life	14-28 days	7 days	9-15 days	4 days	<4-30 days	21-112 days
anaerobic soil metabolism half-life	<7 days	NA	NA[b]	8 days	88 days	NA
Kd[a]	0.05-0.52	0.16[c]	0.03-0.70	0.3-3.9	0.9-4.2	1.08-3.78
# detects/# wells sampled[d]	904/23305	4107/27881	8077/32462	NA	26/1250	0/1368
maximum concentration (ppb) in ground water	395	176	1030	NA	239 (total residues)	0
MCL/HAL (ppb) (Cancer Group)	200 (E)	40 (E)	7 (total residues) (D)	NA	2 (D)	NA

NA Data not available
MCL Maximum Contaminant Level
HAL Lifetime Adult Health Advisory Level.
a Aqueous solubility is expressed as soluble at 20°C; Kd values are expressed in mL/g.
b Aldicarb residues degrade more rapidly under anaerobic conditions than under aerobic conditions.
c A peat soil with an organic matter content of 79.5% had a Kd of 30.
d Monitoring data from various sources; note that sampled wells may not be in pesticide use area.

20

TABLE 4. FUMIGANT NEMATICIDES

parameter	metam sodium (Vapam)	methyl bromide	1,3-dichloropropene[f] (Telone)	Na-tetrathiocarbonate (Enzone)[e]	chloropicrin[f]
vapor pressure (torr)	21.4	1.8×10^3	27.3	25.0	23.8
aqueous solubility	7.2×10^5	1.3×10^4	2.5×10^3	NA	1.6×10^3
hydrolysis half-life	2-4 days	11-15 days	135 days	<24 hours at all pHs	stable
photolysis half-life	28 minutes	9-15 days	NA	<32 hours	NA
aerobic soil metabolism half-life	23 minutes	55 days	12-54 days	3-25 days	< 1 hour
anaerobic soil metabolism half-life	NA	NA	2.4-9.1 days	NA	8-24 hours
Kd	MITC (degradate) is mobile	3.4-6.6	0.23-1.09	NA	NA
# detects/# wells sampled[d]	NA	NA	13/21300	NA	NA
maximum concentration (ppb) in ground water	NA	NA	270	NA	NA
MCL/HAL (ppb) (cancer group)	NA	NA	(B2)	NA	NA

d Monitoring data from various sources; note that sampled wells may not be in pesticide use area.
e Batch equilibrium factors cannot be calculated for enzone due to rapid volatilization of degradates.
f 1,3-dichloropropene and chloropicrin are often formulated together as Telone C-17.

21

REGULATORY OPTIONS

I. Suspend or Cancel or Phase-out or Manage Fenamiphos Use on the Central Ridge of Florida and Other Similar Areas in the U.S.

1. Voluntary Cancellation. Voluntarily withdraw the use of fenamiphos from the Central Ridge of Florida.

Rationale: Detections in shallow ground water from the surficial aquifer on the Ridge greatly exceed the lifetime Health Advisory level. In this area, it is unlikely that other mitigation will reduce concentrations in ground water below the level of concern for human health.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects.

Certainty that option will reduce exposure: High

Negative aspects: At the present time, there are no viable fenamiphos alternative nematicides that can be used for existing citrus on the Central Ridge of Florida. This causes the benefits in this area to be very high.

2. EPA Request for Suspension or Cancellation or Phase-out. Suspend or cancel or phase-out fenamiphos use on the Central Ridge of Florida (this action would be triggered by Florida's draft State Management Plan).

Rationale: Detections in shallow ground water from the surficial aquifer on the Ridge greatly exceed the lifetime Health Advisory level. In this area, it is unlikely that other mitigation will reduce concentrations in ground water below the level of concern for human health.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects.

Certainty that option will reduce exposure: High

Negative aspects: At the present time, there are no viable fenamiphos alternative nematicides that can be used for existing citrus on the Central Ridge of Florida. This causes the benefits in this area to be very high. Continued use will probably not reduce fenamiphos residues in ground water on the Ridge below our level of concern.

3. Develop an agreement between the registrant, Florida, and EPA to manage fenamiphos on the Ridge; allow Florida to manage this restriction.

Rationale: If fenamiphos use is maintained on the Ridge, some form of management strategy must be developed. If Florida manages the strategy, control will be more localized.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects.

Certainty that option will reduce exposure: Depends on details of agreement

Negative aspects: Strategy needs to be developed

4. Suspension in Areas Similar to Central Ridge. The registrant should determine the specific areas in the U.S. similar to those in Florida where conditions (soil types, water table depths, and climatic factors) suggest a high probability of fenamiphos and its degradates reaching ground water. Fenamiphos use in these areas should be suspended.

Rationale: In Florida, fenamiphos has been found to leach to shallow ground water at levels that greatly exceed the lifetime adult health advisory level. Areas with similar hydrogeologic conditions also have the potential to be contaminated by fenamiphos residues.

Anticipated Exposure Reduction: Ground water

Certainty that option will reduce exposure: High

Negative aspects: Alternative nematicides may not be available in these areas. Defining these areas may be difficult.

II. Restrictions

1. All States

a. Revise label to prohibit prophylactic use. Use field surveying, soil/root sampling, and laboratory verification to determine nematode pest infestations prior to application. Treat with fenamiphos only when there is a proven nematode infestation and treat only those areas with the potential for significant nematode damage. Nematode identification and population estimates must be made by certified extension specialists or certified crop protection specialists. Such firms shall also provide growers with written proof of the pest problem; this proof must be given to pesticide dealers in order to purchase fenamiphos.

Rationale: Fenamiphos can be used effectively when a nematode problem is present. If used in a prescriptive manner, less of the pesticide will be used with a decreased effect on the environment. Spot treatments are generally used by growers at the present time.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects.

Certainty that option will reduce exposure: High

Negative aspects: Possible increased cost to growers. Agriculture industry may object to an approach that would require a secondary regulatory level (certified crop protection specialist).

<u>b. Revise Label Rates.</u> The registrant should verify that fenamiphos use rates for all crops (food and nonfood) have been revised to reflect the lowest rates necessary for efficacy.

Rationale: The registrant has voluntarily changed most of the fenamiphos application rates to the typical use rates. These are assumed to be the lowest levels necessary for efficacy but this may not be the case. Reducing the application rates will mean that less of the chemical will be available in the environment.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects.

Certainty that option will reduce exposure: High

Negative aspects: None

<u>c. Propose restricted use classification for ground water concerns.</u>

Rationale: Fenamiphos meets the criteria for classification as a restricted use chemical for ground-water concerns.

Anticipated Exposure Reduction: Ground water.

Certainty that option will reduce exposure: Moderate

Negative aspects: Rule not yet final. The registrant would have to develop training module for Certification and Training programs. There is no guarantee that applicators will use the information.

<u>d. Well Setbacks.</u> Do not apply within 50 feet of any drinking water well with the exception of Florida where more restrictive setbacks apply. In Florida, fenamiphos cannot be applied within 300 feet of any drinking water well. In addition, fenamiphos cannot be used on Florida citrus within 1000 feet of a drinking water well regardless of depth of water table when soils have a permeability rate greater than 20 inches per hour with an available water capacity less than 0.06 in all layers to a depth of 80 inches as identified by the USDA Natural Resources Conservation Service (formerly Soil Conservation Service). Also, as recommended by the registrant in their mitigation proposal, do not apply within 100 feet of property boundaries.

Rationale: Well setbacks are effective at reducing ground-water contamination via poorly constructed wells.

Anticipated Exposure Reduction: Ground water

Certainty that option will reduce exposure: High for point sources

Negative aspects: Useful only where wells are poorly constructed. Will not reduce nonpoint source agricultural leaching.

<u>e. Allow One Application Per Season in Turf.</u> The registrant should check the possibility that one application per season (i.e., in the spring -- mid-April to mid-May) may be adequate if the timing of the application is suitable. If this is an appropriate strategy, the registrant should suggest suitable label language.

Rationale: Healthy root systems are the best way for turf to fight nematode infestations. For all grasses, if fenamiphos is applied when the roots are growing, one application per season may be adequate (two applications are often used). More than one application per season increases the amount of fenamiphos available for movement in the environment. If the application occurs during the "dry" season, less fenamiphos will move to surface or ground water.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects

Certainty that option will reduce exposure: Unknown

Negative aspects: The above option may not be appropriate in all areas because of efficacy problems.

<u>f. Slit Applicators on Turf.</u> The registrant should check on the feasibility of using slit applicators for granular applications on turf.

Rationale: Since the pesticide is applied directly into turf thatch, exposure to wildlife is minimized. If the water inputs are understood and a minimal amount of water is used, the likelihood of the chemical moving to water resources may be reduced.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects

Certainty that option will reduce exposure: Unknown

Negative aspects: Effectiveness is unknown at the present time. Price of equipment is unknown. If water inputs are too high, fenamiphos may leach to ground water. Growers may be resistant to reducing irrigation for fenamiphos-specific management.

g. Surface Water Label Advisory. EFED recommends the following wording for the surface-water label advisory for all uses except tobacco:

"Under some conditions, fenamiphos may have a high potential for runoff into surface water (primarily via dissolution in runoff water) for several weeks post-application. These include poorly draining or wet soils with readily visible slopes toward adjacent surface waters, frequently flooded areas, areas over-laying extremely shallow ground water, areas with in-field canals or ditches that drain to surface water, areas not separated from adjacent surface waters with vegetated filter strips, and areas over-laying tile drainage systems that drain to surface water."

The following statement should also be added to the tobacco label:

"Fenamiphos can contaminate surface water through spray drift from ground spray."

Rationale: Environmental fate information available to the Agency indicate that fenamiphos residues may contaminate surface water.

Anticipated Exposure Reduction: Surface water, eco-effects

Certainty that option will reduce exposure: Unknown

Negative aspects: Label advisory is not enforceable.

2. Florida

In addition to the mitigation options listed above, the following measures are specific to Florida:

a. Well Setbacks. In Florida, fenamiphos cannot be applied within 300 feet of any drinking water well. In addition, fenamiphos cannot be used on Florida citrus within 1000 feet of a drinking water well regardless of depth of water table when soils have a permeability rate greater than 20 inches per hour with an available water capacity less than 0.06 in all layers to a depth of 80 inches as identified by the USDA Natural Resources Conservation Service (formerly Soil Conservation Service). Also, as recommended by the registrant in their mitigation proposal, do not apply within 100 feet of property boundaries.

b. Dry season application/irrigation. In Florida citrus, apply only during the dry season (February to early May) and restrict watering in only to the amount that gets fenamiphos to the necessary depth for efficacy.

Rationale: If fenamiphos is applied during this time, the most excessive rainfall periods will be avoided. Proper irrigation can help ensure that fenamiphos residues do not move to ground water.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects

Certainty that option will reduce exposure: Moderate

Negative aspects: Thunderstorms can always occur during this time. Growers need to properly use the appropriate irrigation equipment. Research will be necessary to determine feasibility.

c. On the Ridge: apply fenamiphos to mature trees only; apply fenamiphos every other year.

Rationale: Fenamiphos applications to mature trees will ensure that the chemical will not be used on new groves. Applications every other year would reduce the amount of fenamiphos available for movement to water resources.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects

Certainty that option will reduce exposure: Moderate

Negative aspects: Although the amount of fenamiphos in the environment will be less if these options are used, there will still be residues that will probably leach to ground water. Efficacy using this procedure is unknown so feasibility needs to be determined.

III. Data Gathering and Education

1. All States

a. Educational Program: Under the product stewardship program, the registrant should develop training materials describing the safe use of fenamiphos that can be disseminated by their distributors. The educational materials should include, at a minimum, written materials suitable for copying and distributing to applicators, and slides accompanied by a text. Videos in VHS format are encouraged.

The training material should focus on the prevention of ground- and surface-water contamination from the use of fenamiphos. The training should stress practices such as:

- using the lowest application rates;
- using less frequent applications per season;
- using efficient irrigation practices to reduce leaching and runoff from the field;
- not applying fenamiphos if rain is forecast for the 24 hours following application;
- ensuring that point sources will not be a source of fenamiphos contamination of water resources; and
- the items noted under Integrated Pest Management (IPM).

The registrant should also make the SNAP (Soil Nematode Analysis Program) readily available to all growers and applicators. The registrant should also improve their stewardship activities with all grower groups for crops on which fenamiphos is used. The focus of these activities should be on turf, citrus, grapes, pineapple, tobacco, peanuts, and peach crops.

In addition, the registrant should actively distribute training materials at agricultural field days. These field days are held in numerous locations around the United States and are an excellent way to reach a broad spectrum of fenamiphos users.

Rationale: Product stewardship and educational materials are important vehicles for the dissemination of information about the safe use of pesticides to a large audience of pesticide applicators. Also, through the use of IPM, it may be possible to minimize fenamiphos use and its impacts on the environment.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects

Certainty that option will reduce exposure: Low to moderate

Negative aspects: Although education is extremely important, there is no guarantee that applicators will use the information.

<u>b. Additional Monitoring/Triggers:</u> The registrant should develop a monitoring plan for other crops and noncrops (i.e., golf courses) in areas where fenamiphos is used, and where conditions are vulnerable, to investigate ground-water and surface-water quality. The monitoring program should be developed in conjunction with the state lead pesticide agency and be subject to final EPA approval.

Rationale: An EPA workgroup was given the task of developing triggers for several chemicals that have been detected in ground water. The workgroup is ongoing and their conclusions will be available in approximately one month. Fenamiphos is not one of the chemicals that was included in the suite for trigger development because it does not meet the monitoring criterion developed by the group.

Almost no ground-water monitoring has been done to evaluate the ground-water impacts of fenamiphos use on crops other than citrus. Little useful monitoring is available in states other than Florida and California (two prospective studies have been started for grapes in California and tobacco in Georgia).

Anticipated Exposure Reduction: Ground water

Certainty that option will reduce exposure: Monitoring will not immediately reduce exposure. Mitigation, if necessary, will be developed following receipt of monitoring data.

Negative aspects: Expense to registrant; requires state resources.

c. Surface-Water Monitoring: Because of potential concerns for surface-water contamination, the registrant should conduct and/or fund existing monitoring programs for fenamiphos and its degradates. Monitoring should be conducted in surface waters and surface-source water-supply systems which drain watersheds typically receiving high fenamiphos applications. The numbers and locations of the systems for which monitoring would be funded, and the duration of the monitoring programs, should be negotiated with EPA.

Rationale: Almost no monitoring has been done to evaluate the impacts of fenamiphos use on surface water resources.

Anticipated Exposure Reduction: Surface water (following data collection)

Certainty that option will reduce exposure: Monitoring will not immediately reduce exposure. Mitigation, if necessary, will be developed following receipt of monitoring data.

Negative aspects: Expense to registrant.

d. Research on Efficacy Reduction in Fenamiphos Use Areas: The registrant should conduct studies to determine the nature and extent of efficacy reduction that occurs with repeated fenamiphos use.

Rationale: A reduction in fenamiphos efficacy has been cited in the literature (Davis et al, 1993; Dunn and Noling, 1993). It is possible that this efficacy reduction may result from accelerated pesticide degradation.

Anticipated Exposure Reduction: Ground water, surface water, eco-effects

Certainty that option will reduce exposure: Unknown (exposure reduction will vary with area)

Negative aspects: Registrant must conduct efficacy studies.

IPM RECOMMENDATIONS

• Citrus: For new citrus plantings, plant certified nematode-free nursery stock. If sites are already infested with problem nematodes, use rootstock resistant to these nematodes.

• Citrus: Adequate water and nutrients will generally offset much of the damage caused by nematodes. Therefore, changes in cultural practices that influence tree vigor through increased nutrient and water availability (irrigation) should be encouraged.

• Turf: Consider using beneficial nematodes to fight sting nematode infestations. This product may not as efficacious as fenamiphos but it will decrease the pest nematode population. Therefore, less fenamiphos will be applied.

• Turf: If herbicides are used on turf, use those herbicides that are not likely to stress (weaken or injure) desirable turfgrasses.

• General: Use cover crops that are non-hosts for the problem nematode. Potentially useful cover crops will vary with the specific pest, crop, and location of the infestation. Other techniques such as fallowing the land may also be practical in some areas.

• General: When possible, rotation with a nonhost crop should be practiced. For example, rotation can be an effective management tool for reducing certain types of cotton nematode populations in some areas.

2. Florida

a. Additional Monitoring/Triggers: Require monitoring for fenamiphos residues on golf courses. If appropriate, new techniques such as slit applicators, beneficial nematodes, and specific herbicides (see IPM section) could be used. Also require detailed information on the exact location and timing of applications so that drinking water wells in these areas can be sampled.

3. Hawaii/Puerto Rico

In addition to the mitigation options listed above, the following measures are specific to Hawaii and Puerto Rico:

a. Pineapple Vulnerability Assessment: In order to estimate the vulnerability of pineapple-growing soils to fenamiphos leaching, the registrant should provide data on the properties of fenamiphos in these soils, the likely range of ground-water depths, and precipitation and irrigation needed to grow pineapples in these areas.

Rationale: Little information is available about the effects of fenamiphos use on water resources where pineapples are grown. Label rates for this use are high.

Anticipated Exposure Reduction: Ground water, surface water

Certainty that option will reduce exposure: Need data to decide on certainty.

Negative aspects: Utility will be unknown until data are presented.

BIBLIOGRAPHY

Barnett, Bill. 1996. Mississippi Department of Environmental Quality, personal communication.

Davis, R.F., Johnson, A.W, and R.D. Wauchope. 1993. Accelerated Degradation of Fenamiphos and Its Metabolites in Soil Previously Treated with Fenamiphos, Journal of Nematology 25(4):679-685.

Duncan, Larry. 1996. Florida Fruit and Vegetable Growers Association, Environmental and Pest Management Division, personal communication.

Dunn, R.A. and J.W. Noling. 1993. Florida Nematode Control Guide.

Erickson, Dennis. 1996. Washington State Department of Ecology, personal communication.

Florida Department of Agriculture and Consumer Services, Florida Department of Environmental Protection, Florida Department of Health and Rehabilitative Services. Draft Generic State Management Plan for Pesticides in Ground Water.

Fortnum, Bruce. 1996. Clemson University, South Carolina, personal communication.

Hoheisel, C., J. Karrie, S. Lees, L. Davies-Hilliard, P. Hannon, R. Bingham, E. Behl, D. Wells, E. Waldman. 1992. Pesticides in
round Water Database - A Compilation of Monitoring Studies: 1971 - 1991. Office of Prevention, Pesticides, and Toxic Substances. EPA 734-12-92-001. September 1992.

Martin, Bruce. 1996. Clemson University, South Carolina, personal communication.

Mathews, Charles. 1996. Florida Fruit and Vegetable Growers Association, Environmental and Pest Management Division, personal communication.

McLaughlin, Mark. 1996. Oregon Department of Environmental Quality, Water Quality Division, personal communication.

Miles and Pfeuffer. 1994. South Florida Water Management District.

Noling, Joe. 1996. Citrus Research and Education Center, Lake Alfred, FL, personal communication.

O'Hare, Jeannette. 1996. Texas Natural Resources Commission, personal communication.

Rhone-Poulenc and The Cotton Foundation. 1993. Cotton Nematodes - Your Hidden Enemies, produced by the Beltwide Cotton Nematode Survey and Eduction Committee

32

Segawa, Randy. 1996. California Department of Pesticide Regulation, personal communication.

Swancar, Amy. 1996. Water Quality, Pesticide Occurrence, and Effects of Irrigation with Reclaimed Water at Golf Courses in Florida, U.S. Geological Survey Water-Resources Investigations Report 95-4250, Tallahassee, FL.

Thornton, John S. 1994. Letter from Miles Inc. to Marion Fuller (FDACS), May 23, 1994.